

Apparatus for Treating Substrates

Smz A, 7

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The present invention relates to an apparatus for treating substrates, especially semiconductor wafers, and includes a process container having at least one opening, whereby the opening can be closed from the outside by the substrate.

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An apparatus for treating substrates is known, for example, from Applicant's not prepublished DE 198 59 470. This apparatus has an upwardly open process tank through which a metal-containing electrolyte flows from the bottom toward the top. Along its path toward the top, the electrolyte flows through an anode that is embodied as an extended grating. A semiconductor wafer, which is to be plated with the metal found in the electrolyte, is held by a substrate holder over an upper edge of the process container in such a way that a flow gap is formed therebetween. The electrolyte that flows through the process tank is caused to overflow between the upper edge of the process container and the substrate, and is brought into contact with the wafer. By applying a voltage between the anode and the wafer, which is electrically contacted, the metal that is contained in the electrolyte is caused to deposit upon the wafer.

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With this apparatus, due to the aforementioned flow against the substrate, there results in the outer edge regions of the wafer, especially in the region of the gap between the wafer and the upper edge of the process container, higher flow speeds than in the central portion of the wafer. Due to these flow inhomogeneities, deposition inhomogeneities of the metal upon the wafer result. Gas bubbles that result during the deposition of the metal are generally carried along by the flow of the electrolyte, although they can collect in areas of relatively calm flow, where they adversely affect a further deposition of metal. Since the electrolyte flows through the anode that is disposed across from the wafer, the anode must have large flow openings, which adversely affect the production of a homogeneous electrical field between the anode and the wafer. For a further treatment of the wafer, such as a rinsing process, the substrate must be raised and possibly a rinsing-drying unit must be moved beneath the wafer, with such a unit being described in Applicant's not prepublished DE 198 59 469.

U.S.-A-5,437,777 discloses an apparatus for the treatment of substrates of the aforementioned type, according to which an opening of a process container is closed from the outside by a substrate that is to be treated. The opening is disposed in a vertical wall of the process container in order to achieve during a metal plating process a uniform

flow of a treatment fluid against the substrate. After a plating process, the substrate must be transferred in a complicated procedure in order to be treated, for example to be rinsed, in a further process container. During the transfer there results the danger of damage to the substrate due to the required handling steps. There furthermore exists the danger during the transfer that the treatment fluid dries on during the required transfer time and thereby damages the substrate.

It is therefore an object of the present invention to provide an apparatus of the aforementioned general type that enables a simple, homogeneous treatment of a substrate surface that is to be treated, and reduces the danger of damage to the substrate between successive treatment steps.

This object is inventively realized in that for the apparatus described initially a second process container is provided adjacent to the first process container, wherein a wall of the second process container is at least partially that container wall of the first process container that contains the opening. By providing the second process container, which shares with the first process container the wall that contains the opening, the substrate is disposed in the second process container during the treatment in the first process container, and after the

treatment in the first process container can be treated in the second container without any further transfer. The time periods between successive treatment steps can be considerably reduced, thereby considerably reducing the danger of having the treatment fluid dry on.

5 If the substrate does not close off the opening in the process containers, this opening is closed off from the side of the first process container in order to provide a separation of the two process containers. The provision of two separate process chambers furthermore reduces the carrying off of medium or the mixing of
10 different media. By closing the opening of the first process container from the outside via the substrate, there is ensured in a straightforward manner that only that surface of the substrate that faces the process container will come into contact with a treatment fluid located in the process container, whereas the remaining portions of the substrate are
15 insulated therefrom. Furthermore, a lateral flow against the substrate is possible, with such flow extending essentially parallel to the substrate surface. As a result, a uniform flow against the substrate surface, and hence a uniform treatment, are achieved.

20 Pursuant to one particularly preferred specific embodiment of the present invention, the opening is formed in an essentially vertical wall of the process container, as a result of which, during filling of the

invention, the apparatus is provided with an electrode disposed across from the opening in order to generate an electrical field between the electrode and the substrate. In this connection, the electrode is preferably an electrode plate that makes it possible to apply a homogeneous electrical field. Pursuant to one preferred specific embodiment, the electrode plate has openings to allow at least one fluid, especially a drying fluid, to pass through in order to enable a directed, perpendicular fluid flow against the substrate that is disposed across from the electrode. The electrode is preferably an anode.

Pursuant to a further preferred specific embodiment of the invention, the electrode can be moved toward and away from the opening in order to adjust, if desired, the spacing between the electrode and the substrate. The opening of the process container can preferably be closed from the inside by the electrode in order to close off the process container from the atmosphere when it is not closed off by the substrate.

To ensure a sealed closing off of the opening by the electrode, at least one sealing element is provided on the electrode and/or on a container wall that surrounds the opening. In order to prevent impairment of the electrical field generated by the electrode, as well as on the substrate

side to prevent negative impacts from a fluid flow, the sealing element preferably radially surrounds the electrode and projects axially beyond a surface of the electrode that faces the opening.

5 Pursuant to one special specific embodiment of the apparatus, which serves for the metal plating of the substrate, at least one treatment fluid that can be introduced into the process container is a metal-containing electrolyte and/or an etching medium.

10 The second process container preferably forms a rinsing and/or drying chamber and/or a surface-conditioning chamber.

20 Pursuant to one preferred specific embodiment of the invention, the substrate is held by a substrate holder having at least one vacuum finger that is moveable relative to a main body of the substrate holder. By providing a vacuum finger that is moveable relative to the main body of the substrate holder, the substrate can be loaded and removed at a distance from the main body of the substrate holder, so that a substrate handling mechanism can be moved between the substrate and the main body of the substrate holder. For a reliable and uniform holding, the vacuum finger is preferably centrally arranged in a surface of the main body that faces the substrate. To bring the main body of

the substrate holder into contact with the substrate, the vacuum finger is preferably recessible in the main body.

Pursuant to one preferred specific embodiment of the invention, a pressure sensor is provided in a vacuum line that is connected with the vacuum finger in order to let a wafer handling mechanism, which brings the substrate to the substrate holder, know when the substrate is reliably held on the vacuum finger.

In addition to the vacuum finger, the substrate holder preferably has a plurality of fixed vacuum openings in that surface of the main body that faces the substrate in order to fixedly hold the substrate on the substrate holder over larger areas. In this connection, the vacuum openings preferably radially surround the vacuum finger. The vacuum openings can advantageously be supplied with vacuum separately from the vacuum finger.

Pursuant to one preferred specific embodiment of the invention, at least one sealing element that radially surrounds the vacuum openings is provided on the substrate holder in order to ensure a good sealing of a vacuum region. The sealing element on the substrate holder is preferably elastic, and is disposed across from the sealing element on

the periphery of the opening, in particular the sealing lip, in order to provide the substrate in this region with a small movement clearance, thereby preventing the substrate from becoming damaged, in particular becoming crushed, between the sealing element at the periphery of the opening and the substrate holder. By providing the two sealing elements across from one another, the contact pressure is additionally transferred directly vertically by the substrate without transverse forces or tensions occurring in the substrate.

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The present invention will be explained subsequently with the aid of preferred specific embodiments with reference to the figures. In the drawings:

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Fig. 1 is a schematic illustration of one exemplary embodiment of the inventive embodiment;

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Fig. 2 is an enlarged schematic illustration of the encircled portion of Fig. 1;

Fig. 3 is an alternative specific embodiment of the invention having two process containers.

Fig. 1 shows metal-plating apparatus 1 that includes a process container 2, an anode arrangement 3 that is moveably disposed within

the process container 2, and a substrate holder 4 that is disposed outside of said process container 2.

The process container 2 is formed by a bottom wall 6, a top wall 7, and appropriate side walls, of which a left side wall 8 and a right side wall 9 are shown. A process chamber 10 is formed between the walls of the process container 2. Provided in the bottom wall 6, next to the right side wall 9, is a combined inlet and outlet opening 11 that communicates with a conduit 12. By means of the conduit 12, i.e. the opening 11, a treatment fluid can be introduced into as well as discharged from the process container 2. Instead of a combined inlet and outlet connection, it would, of course, also be possible to provide two separate openings having corresponding conduits.

Provided in the top wall 7 is an opening 14 that communicates with an overflow conduit 15. The treatment fluid that is introduced from below flows out of the process container 2 via the opening 14 and the overflow conduit 15.

Provided in the left side wall 8 is a central opening 17 in which is disposed a displacement rod 19 of the anode arrangement 3. The displacement rod 19 of the anode arrangement 3 extends through the

central opening 17 and is connected on that end thereof that is disposed outside of the process container 2 with a non-illustrated linear movement unit. The end of the displacement rod 19 that is disposed within the process container 2 is connected to an anode plate 20 that extends parallel to the side wall 8 and essentially perpendicular to the displacement rod 19. The anode plate 20 is a closed plate having a planar surface 21 that faces the right side wall 9. Provided between the left side wall 8 and the rear side of the anode plate 20 is a seal member in the form of an O-ring 23 that is secured either to the side wall 8 or to the rear side of the anode plate 20. The anode plate 20 is radially surrounded by an O-ring 25 that projects beyond the surface 21 of the anode plate 20 in a direction toward the right side wall 9. The reference 26 indicates a sealing bellows that on its left side is connected to the displacement rod 19 and on its right side is connected to the first wall 8 of the container 10.

The right side wall 9 has a central opening 29, the dimensions of which are less than the dimensions of a substrate that is to be treated, such as a semiconductor wafer 31. The periphery of the opening 29 is formed by a seal 32, which can be best seen in the detailed view of Fig. 2. The seal 32 is fused or welded to an inner periphery of the right side wall 9, and is provided with a curved surface 33 that is directed

toward the opening 29. Formed in that side of the seal 32 that is opposite the surface 33 is an undercut 35 that is formed, for example, by milling out the material that forms the seal 32.

On the outer side of the container wall 9 a contact element 37 in the form of a contact spring is secured by means of a screw. The contact element 37 extends into the region of the undercut 35 of the seal 32 and is provided with _____ cusp on?? a rounded contact end 39. The rounded contact end 39 serves for the electrical contact of a rim region of a surface 40 of the wafer 31 that faces the process container 2. The electrically contacted rim region of the surface 40 of the wafer 31 is disposed radially beyond a contact region between the surface 40 and the seal 32, and is thus insulated relative to the interior of the ~~process container 2.~~

The wafer 31 is carried by the substrate holder 4 and is moveable therewith toward the process container into a position in which the wafer 31 closes off the opening 29 in the side wall 9, and is moveable away from the process container 2 into a position in which the wafer 31 does not close off the opening 29.

The substrate holder 4 is provided with a main body 42 and a

displacement rod 43 that is secured thereto. The displacement rod 43 can also be monolithically formed with the main body 42. Disposed in the main body 42 is a centrally arranged vacuum finger 44 that communicates with a vacuum line 45. Disposed in the vacuum line 45 is a non-illustrated pressure sensor that determines whether a sufficient vacuum for holding the wafer is maintained between the vacuum finger 44 and the wafer 41.

The vacuum finger 44 is laterally moveable out of and retractable into the main body 42, so that it is completely recessed in the main body 42. Furthermore provided in the main body 42 are a plurality of openings 47 that radially surround the vacuum finger 44 and communicate with a vacuum line 48 and that can further be supplied with a negative pressure or vacuum in order to pull the wafer 31 securely against the main body 42 of the substrate holder 4. The vacuum lines 45 and 48 can be separately supplied with a vacuum, although they could also be connected to a common source of vacuum.

As can be seen in Fig. 2, a groove 50, which accommodates an O-ring 51, is provided in the rim region of a surface of the main body 42 that faces the wafer 31. The O-ring 51 radially surrounds the vacuum openings 47 and thus provides a good radial seal of a vacuum area

formed between the wafer 31 and the main body 42 of the substrate holder 4. The O-ring 51 is disposed against the side wall 9 of the process container 2 in the region of the seal 32.

5 The treatment of the wafer 31 in the apparatus of Fig. 1 will be described subsequently.

10 The substrate holder 4 is first retracted and spaced from the process container 2. The vacuum finger 44 is moved out of the main body 42 of the substrate holder 4 and receives a wafer 31 that is brought into the region of the substrate holder 4 by a non-illustrated handling mechanism. The extended vacuum finger 44 makes it possible to move the handling mechanism into a space formed between the main body 42 and the substrate 31 and to transfer the substrate to the vacuum finger 44.

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20 After receipt of the substrate by the vacuum finger 44, the handling mechanism is released and moved out of the region between the wafer 31 and the main body 42 of the substrate holder 4. The vacuum finger 44 is then retracted into the main body 42 of the substrate holder 4. In so doing, one side of the wafer 31 comes into contact with the main body 42, and a vacuum is applied via the vacuum line 48 to the

vacuum openings 47 to ensure a reliable holding of the wafer 31 on the main body 42.

The substrate holder 4 is subsequently moved toward the process container 2 until the surface 40 of the wafer 31 comes into contact with the seal 32 on the side wall 9, thereby closing off and sealing the opening 29 in the side wall 9. At the same time, the rim region of the surface 40 of the wafer 31 comes into contact with the rounded contact end 39 of the contact element 37.

The process container 2 is subsequently filled with a metal-containing electrolyte, whereby the surface 40 of the wafer 31 is uniformly wetted with the electrolyte. A voltage is subsequently applied between the anode plate 20 and the electrically contacted wafer 31 in order to effect a deposition of the metal contained in the electrolyte upon the surface 40 of the wafer 31. In this connection, electrolyte is continuously introduced into the process container 2 via the opening 11 and flows out of the process container 2 via the opening 14. After an adequate deposition of the metal, the electrolyte is discharged from the process container 2 via the opening 11. During retraction of the substrate holder 4 from the process container 2, the anode plate 20 is moved through the process container 2 toward the side wall 9 until the seal 25

comes into contact with an inner surface of the side wall 9. In this way, the opening 29 of the process container 2 is sealed off from the inside and prevents contamination from entering the process container 2.

Alternatively, prior to moving the substrate holder 4 away, a rinsing and/or drying of the wafer 31 can be effected within the process container 2. To rinse the wafer 31, rinsing fluid is introduced into the process container 2 via the opening 11 or a separate opening, and the surface 40 of the wafer 31 is rinsed. To dry the wafer 31, the rinsing fluid is slowly discharged, whereby first a solvent, such as an IPA layer, is applied to the surface of the rinsing fluid so that a drying is effected pursuant to the Marangoni principle.

Alternatively, openings can be provided in the anode plate 20 for allowing a drying fluid to pass through (as will be described subsequently in conjunction with Fig. 3.) Then, after discharge of the rinsing fluid, the anode plate 20 is moved into a position adjacent to the substrate 31 and drying fluid, such as N₂, is introduced via the openings onto the surface 40 of the substrate 31 in order to dry the same.

The substrate holder 4 is subsequently moved away from the side wall

9 so that the wafer 31 can be removed from the substrate holder 4.

Fig. 3 shows an alternative embodiment of the present invention, according to which the metal-plating apparatus 1 is embodied in the form of a vertical dual process chamber. To the extent that this is expedient, in Fig. 3 the same reference numerals are used as with the embodiment of Fig. 1 in order to designate the same or similar elements.

The apparatus 1 has a first process container 2 that is essentially the same as the process container 2 of Fig. 1, as well as a second process container 60.

The process container 2 has a bottom wall 6, a top wall 7, as well as left and right side walls 8 and 9. Provided in the bottom wall 6 is a discharge opening 62 that communicates with a conduit 63.

Provided in the side wall 8, in the region of the bottom wall 6, is an inlet opening 64 that communicates with an inlet conduit 65.

Furthermore provided in the side wall 8, in the region of the top wall 7, is an overflow opening 66 that communicates with a conduit 67.

A displacement rod 19 of an anode arrangement 3 extends through a central opening 17 in the side wall 8 and is longitudinally displaceable within the process container 2.

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Provided in the displacement rod 19 is a longitudinally extending passage 70 that communicates with a non-illustrated source of fluid.

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An anode plate 20 of the anode arrangement 3 is provided with radially outwardly extending passages 72 that communicate with the passage 70 in the displacement rod 19. The passages 72 communicate with openings 74 in a surface 75 of the anode plate 20 that faces the side wall 9. By means of the passage 70, the passages 72 as well as the openings 74, a fluid, such as N₂, can be conveyed through the anode arrangement 3. The surface formed by the opening is very small in comparison to the overall surface area of the surface 75 of the anode plate 20, so that the anode plate 20 can be seen as an essentially closed plate. As with the first exemplary embodiment, the anode plate 20 is radially surrounded by an O-ring 25. Again, a sealing bellows 26 is provided that on one side is connected to the displacement rod 19 and on the other side is connected with the first wall 8 of the container 10.

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The side wall 9 is again provided with an opening 29, the periphery of which is determined by a seal 32. The opening 29 can again be closed off from the outside by a wafer 31 and from the inside by the anode plate 20.

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Provided adjacent to the first process container 2 is a process container 60, the left side wall of which is formed by the right side wall 9 of the first process container 2, which right side wall contains the opening 29. The second process container 60 is provided with a bottom wall 76, a top wall 77, the left side wall 9 as well as a right side wall 78. Provided in the bottom wall 76 is a combined inlet and outlet opening 81 that communicates with a conduit 82. Instead of a combined inlet and outlet opening, it is of course also possible to provide two separate openings.

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Provided in the top wall 77 is an opening 84 that communicates with a conduit 85.

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Provided in the right side wall 78 of the process container 60 is a central opening 87 through which extends a displacement rod 43 of the substrate holder 4. The reference 91 shows a sealing bellows that at

one end is connected with the displacement rod 43 of the substrate holder 4 and at its other end is connected with the right side wall 78 of the process container 60.

5 Disposed on or in the left side wall 9 of the second process container 60 is a nozzle 90 that faces the second process container 60 and via which a treatment fluid, such as a rinsing fluid, in particular deionized water, is introduced into the second process container 60. Instead of a single nozzle, a plurality of nozzles could also be provided.

10 The construction of the substrate holder 4 corresponds essentially to the construction of the substrate holder 4 of Fig. 1, whereby merely the form of the vacuum finger 44 as well as the form of the vacuum openings 47 differs from that shown in Fig. 1.

15 The operating sequence of the vertical dual process chamber is as follows:

20 The wafer 31 is vertically introduced into the second process container 60 via a non-illustrated, lateral opening thereof and by means of a wafer handling mechanism, and the wafer is accommodated on the substrate holder 4 in the manner described above. The substrate

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holder 4 is subsequently moved in a direction toward the wall 9 until the wafer surface 40 comes into contact with the seal 32 on the opening 29, and the process containers 2 and 60 are sealed relative to one another. At the same time, the surface 40 of the wafer is electrically contacted in the manner described above directly behind the seal 32.

After the process chambers have been sealed, a metal-containing electrolyte is introduced into the process container 2 via the opening 64 until it overflows the opening 66. A voltage is thereafter applied between the wafer 31 and the anode plate 20, resulting in a deposition of metal upon the surface 40 of the wafer 31. After conclusion of the deposition process, the electrolyte is discharged from the process container via the opening 62.

The substrate holder 4, with the wafer 31 held thereon, is subsequently moved away from the common wall 9 of the process chambers 2 and 60. At the same time, the anode arrangement 3 is moved in a direction toward the wall 9 until the O-ring 25 comes into contact with the common wall 9 and the two process containers 2 and 60 are sealed relative to one another by the anode arrangement 3.

Rinsing fluid, for example deionized water, is now introduced via the

nozzle 90 and/or the opening 81 into the second process container 60 and the wafer is rinsed. After an adequate rinsing, the deionized water is discharged. To dry the wafer, a drying fluid, such as N₂, is then introduced into the process container 60 via the opening in the anode, and is blown against the wafer. For the drying process, the spacing between the anode plate and the wafer 31 can be reduced by moving the substrate holder 4 toward the wall 9.

As an alternative drying variation, the Marangoni principle can also be utilized. For this purpose, prior to the discharge of the deionized water, a solvent, such as IPA, is introduced into the process container 60 from above via the opening 84. The deionized water is subsequently discharged, and the wafer 31 is dried pursuant to the Marangoni principle.

The thus treated and dried substrate is subsequently removed from the non-illustrated lateral opening of the container 60.

The present invention has been described with the aid of preferred specific embodiments of the invention, without, however, being limited to the specific embodiments. For example, it is not necessary for the opening 29, which can be closed off by the wafer 31, to be formed in a

